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ADDENDA ET CORRIGENDA.

Page 37, after the Note (a) add the following quotation from Van Swieten.

Vidi integram familiam hoc morbo (ſcilicet Colica Pictonum) laboraſſe, dum ad culinares uſus adhibebatur aqua, in magno receptaculo plumbeo collecta, et diu hærens.

Comment. Vol. 3. p. 357.

Page 51, line 13, for---gum arabic ten grains, read ---gum arabic three grains.

Page 63, line 12, for---encreaſed, read---increaſed.

Experiments and Obſervations

ON

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> *Sapientis medici eſt, eorum locorum aquas ubi medicinam facit, convenienti examine probè ſcrutari, quo poſtea cum fructu, tam præſervandi quam ſanandi gratia, ijs uti poſſet.*
>
> HOFFMAN.

EXPERIMENTS
AND
OBSERVATIONS
ON
WATER:
Particularly on the
HARD PUMP WATER
OF
MANCHESTER.

BY

THOMAS PERCIVAL, M.D. F.R.S.

> —— *Sanctos auſus recludere fontes.*
>
> VIRGIL.

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THE

INTRODUCTION.

THE extenſive influence of WATER on the health of mankind will, it is hoped, appear ſufficiently evident from the following Eſſay. The author propoſed to have enlarged the ſubject of it, by enquiring into the effects of hard and ſoft water on a variety of the common arts of life, ſuch as Brewing, Malting, Dying, Bleaching, Tanning, &c. &c. But he found the ſubject too copious, to be reduced within the bounds which he had preſcribed to himſelf; and that the proſecution of it, would too much abſtract his attention from thoſe favourite ſtudies, which more immediately belong to his profeſſion.

THIS Eſſay was intended only to be communicated to the ROYAL SOCIETY: And many of the experiments contained in it, have been read before that learned body. But the importance of the ſubject, and a deſire of rendering his little work more diffuſively uſeful, hath induced the author to publiſh it. And he flatters himſelf, that he ſhall at leaſt be juſtified by the motives, if not by the ſucceſs of his undertaking.

Mancheſter,
Nov. 1, 1768.

EXPERIMENTS
AND
OBSERVATIONS
ON
WATER.

SECTION I.

IT is a maxim of the divine Hippocrates, that whoever would apply with ſucceſs to the ſtudy of phyſick, ſhould acquaint himſelf with every circumſtance relating to the ſituation of the place wherein he practiſes, the nature of the ſeaſons, the influence of the winds, and the particular qualities of the water. The laſt object is by far the moſt important; becauſe as a fixed and permanent cauſe, its effects will be regular, uniform, and conſtant. For whether the ſimple element itſelf be uſed, or it be mixed with vinous liquors, or brewed into beer, it will ſtill retain in ſome meaſure its peculiar properties, and if impure, will gradually produce ſome morbid changes in the body. On the robuſt indeed, its action may perhaps be ſlow, and imperceptible; but the tender and valetudinary will find themſelves ſooner and more ſenſibly affected by it. Many of the diſeaſes of children, it is more than probable, owe their riſe to this neceſſary diluent and vehicle of their food. And if we conſider that numberleſs chronic diſorders, have their foundation laid in the ſtate of infancy and childhood, the influence of water on the health of mankind, will appear to be very extenſive, and deſerving of our ſtricteſt attention and regard. It would be no difficult matter to prove, that a conſiderable number of thoſe diſtempers, which from their being peculiar to certain people and places, are termed endemic, are chiefly the effects of this powerful and active cauſe. Thus the inhabitants of the Alps, the Pyrenees, and of many other mountainous countries, are ſubject to a monſtrous external ſwelling of the glands of the neck, owing as it is univerſally acknowledged, to the peculiar properties of the water they drink (a). " As you advance towards Mount Cenis, ſays Mr. Sharp, in his excellent Letters from Italy, you find very few exempt from theſe tumours, which are ſo enormous, and of ſo loathſome an appearance, eſpecially in ugly, ragged, half-ſtarved old women, that the very ſight of them turns the ſtomach. I was curious in my examination, whether any children are born with this malady upon them: I was informed,

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(a) *Quis tumidum guttur miratur in Alpibus?*

Juvenal. Sat. 13.

that there is no ſuch inſtance; and even that the ſwelling never begins to form 'till towards two years of age; ſome examples of which I myſelf ſaw" (b). Nor is this diſtemper peculiar to the natives of thoſe countries; for ſtrangers become affected with it, after reſiding there a few years (c). And ſuch is the influence of cuſtom on the common people, that they regard this blemiſh as a beauty, and even ridicule thoſe who are deſtitute of it. The inhabitants of the village of Steinſeffein, in the diſtrict of Schmiderberg, are ſaid to have freed themſelves from this malady, by abſtaining from certain fountains, which were obſerved to produce it (d). In two cities of Hercynia, Wildeman, and Andreaſberg, which are built upon a large bed of minerals, ſcarcely a woman is to be found, who does not labour under ſtrumous ſwellings of the throat, occaſioned it is juſtly ſuppoſed, by the conſtant uſe of hard, metallic, and calcareous water (e). The men too, in all probability, are not exempt from them; but as the female part of our ſpecies have more delicate conſtitutions, and eſpecially a much greater degree of laxity in their glandular ſyſtems than we have, the ſame cauſes which but ſlightly affect the one ſex, may prove highly injurious to the other. The people of Siberia, who live near the river Kirenga, which is remarkable for its impurity, are almoſt univerſally affected with ſcrophulous diſorders; and ſtrumous ſwellings are common, even amongſt the cattle of that country (f).

(b) Sharp's Letters, p. 298.

(c) Hoffman. Op. Tom. 6. p. 202.

(d) Id. p. 203.

(e) Hoffman. Op. Tom. 6. p. 203.

(f) Comment. Lips. Tom. 2. p. 103.

Hippocrates aſſerts that hard waters, which are unfit for boiling, dry and aſtringe the belly; and that ſuch as are ſtagnant and ill-ſcented, injure both the belly and ſpleen (g). In confirmation of this, it may be obſerved, that in Minorca, where the water which the ſprings and rivulets afford, is often brackiſh, and always hard, obſtructions, indurations, and ſwellings of the abdominal viſcera, together with flatulency and indigeſtion, are the moſt common diſeaſes to which the inhabitants are ſubject. And it is remarkable, that large ſpleens and tumefied livers are not peculiar there to the human ſpecies, but are incident alſo to brutes; eſpecially to the ſheep, which feed on the eaſtern ſide of the iſland, where the waters are particularly brackiſh (h).

(g) Hippoc. *de Aere, Aquis et Locis.*

(h) Vid. Cleghorn on the Diſ. of Minorca.

PLINY mentions a fountain in Æthiopia, about which a large quantity of native cinnabar was found, and which produced its deleterious effects chiefly on the brain (i). And Athenæus ſpeaks of a ſpring in Paphlagonia, to which the inhabitants of the country frequently reſorted, which had an inebriating quality. Ovid poetically deſcribes ſuch waters in the following lines.

Cui non audita eſt obſcenæ Salmacis undæ,
Æthiopeſque lacus? quos ſi quis faucibus hauſit,
Aut furit, aut patitur mirum gravitate ſoporem.

Metamorph. lib. 15, 317. 321.

THE *Plica Polonica*, a ſingular diſeaſe to which the inhabitants of Poland and Lithuania are ſubject, and which conſiſts in a præternatural enlargement and convolution of the hair, is in part aſcribed by a very celebrated writer, to the uſe of impure water. *Morbi hujus cauſa valde perplexa & difficilis videtur, nihilominus eam, quantum fieri poterit, indagare allaborabimus. Primo multum ſordidum vitæ genus confert, cui hi populi addicti ſunt; dum raro crines pectunt in humidis et depreſſis locis dormiunt, et ſpiritum vini liberaliſſimè ingurgitant. Suum quoque ſymbolum aquæ contribuunt; hinc non male Gehema in Epiſtola ad Bontekoe, de Plica Polonica pag.* 10. *ſentit, hærere vitium in nonnullis Poloniæ aquis*, &c.

(i) Plin. Hiſt. lib. 31. c. 2.

——— *Nos ſupponimus quoddam vitium hæreditarium, quod in nimia pororum et bulborum capillorum ſub cute in capite conſiſtit; unde ſuccus nutritius, craſſus, et glutinoſus, pravâ diætâ ex* CRUDIS AQUIS *productus, calore, quem potus ſpiritus vini conciliat, urgetur ad tubulos capillorum, ex quorum poris exſudat, et monſtroſam illam intricationem efficit*

ſicit (k).—This ſuppoſition of the learned Hoffman is confirmed by the following aphoriſm of Sanctorius. Heavy water and a foggy air, convert the matter of perſpiration into an ichor, which when retained in the body, induces a cachexy (l).

Dr. Mead in the firſt edition of his Eſſay on Poiſons, relates the caſe of a lady, whoſe life was formerly imbittered by the frequent returns of violent colic pains, 'till ſhe was happily adviſed by her phyſician, not to drink, as ſhe uſually did, beer, brewed with well water. And ſo evidently was the eſtabliſhment of her health owing to this caution, that the neglect of it was always attended with a return of her diſorder. A fact ſimilar to this is recorded

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(k) Vid. Hoffman. Op. Tom. 6. p. 205.

(l) Sanctor. Med. Stat. Sect. 2. Aph. 6.

corded by Van Helmont, of the monks belonging to a certain monaſtery near Bruſſels, who were always affected with the gripes by the water which they uſed, unleſs they corrected its effects by boiling wild carrot ſeed in their beer (m).

It is an opinion which the father of phyſick firſt advanced, and which has been almoſt univerſally adopted by his followers, and hath remained 'till lately uncontroverted, that the ſtone and gravel are generated by the uſe of hard water. *Damnantur imprimis fontes*, ſays Pliny, *quorum Aquæ decoctæ, craſſis obducunt vaſa cruſtis* (n). And from this quality, which the waters of certain ſprings poſſeſs, of depoſiting a large earthy ſediment, either in the aquæducts through which they are conveyed, or in the veſſels in which they are boiled or preſerved, it was obvious to infer, that in paſſing thro' the kidneys, and eſpecially whilſt retained in the bladder, they would let fall their groſſer particles, which by the continued appoſition of freſh matter, connected by the animal gluten, and compacted by the muſcular action of that organ, would in time form a *Calculus*, ſufficiently large to produce a train of the moſt excruciating ſymptoms. And this reaſoning *à priori*, has been ſuppoſed to be confirmed by facts and experience; for not to mention the authority of Hippocrates, Dr. Liſter has obſerved, that the inhabitants of Paris, are peculiarly ſubject to the ſtone in the bladder (o). And it is well

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(m) Helmont's Lithiaſis.---Vid. alſo Hale's Stat. Eſſays. Vol. 2. p. 248.

(n) Lib. 31. c. 3.

(o) Vid. Liſter's Journey to Paris.

known, that the water of the river Seine, with which that city is ſupplied, is ſo impregnated with calcareous matter, as to incruſtate, and in a ſhort time to choak up the pipes through which it runs. But on the other hand it is objected, that the human *Calculus* is of animal origin, and by chemical analyſis, appears to bear very little analogy to the ſtony concretions of water. And though it is allowed, that more perſons are cut for the ſtone in the hoſpitals at Paris, than in moſt other places, yet upon enquiry it is found, that many of thoſe patients come from different provinces, and from towns and villages far diſtant from the Seine.

Non noſtrum inter hos tantas componere lites.

But if I may be allowed to indulge a conjecture, I ſhould ſuppoſe, that though this diſeaſe may chiefly depend upon a peculiar diſpoſition to concrete in the animal fluids, which in many inſtances is hereditary, and in no inſtance can with certainty be imputed to any particular cauſe; yet, hard water is at leaſt negatively favourable to this *diatheſis*, by having no tendency to diminiſh it. The urine of the moſt healthy perſon, is generally loaded with terreous matter, capable, in favourable circumſtances, of forming a *Calculus*; as is evident from the thick cruſt which it depoſits, on the ſides of the veſſels in which it is contained. And it ſeems as if nature intended by this excretion, to diſcharge all the ſuperfluous ſalts of the blood, together with thoſe earthy particles, which are either derived from our aliment, and fine enough to paſs through the lacteals, though inſuperable by the powers of circulation, or which ariſe from the abraſion of the ſolids, or from the diſſolution of the red globular part of our fluids. Now water, whether uſed as nature preſents us with it, or mixed with wine, or taken under the form of beer or ale, is the great diluter, vehicle, and *menſtruum* both of our food, and of the ſaline, earthy, and recrementitious parts of the animal juices. And it is more or leſs adapted to the performance of theſe offices, in proportion to its degree of purity. For it muſt appear evident to the moſt ordinary underſtanding, that a *menſtruum* already loaded, and perhaps ſaturated, with different contents, cannot act ſo powerfully as one which is free from all ſenſible impregnation. Nor is this reaſoning founded upon theory alone (p); for it is obſerved, that MALVERN WATER, which iſſues from a ſpring in Worceſterſhire, remarkable for its uncommon purity, hath the property of diſſolving the little ſabulous ſtones, which are often voided in nephritic complaints. And the ſolution too, which is a proof of its being complete, is perfectly colourleſs. Hence this water is drunk with great advantage in diſorders of the urinary paſſages. And during the uſe of it, the patient's urine is generally limpid, and ſeldom depoſits any ſandy ſediment. Yet notwithſtanding this appearance of tranſparency, it is certainly at ſuch times, loaded with impurities, which are ſo diluted and diſſolved as not to be viſible. For it is attended with a ſtrong and fœtid ſmell, exactly reſembling that of aſparagus (q).

(p) A gentleman of this place, who had been long ſubject to nephritic complaints, and often voided ſmall ſtones, was adviſed to refrain from the uſe of his own pump water, which is uncommonly hard, and to drink conſtantly the ſofter water of a neighbouring ſpring. And this change alone, without the uſe of any medicine, hath rendered the returns of his diſorder much leſs frequent and painful.

Vid.

(q) In Nephritic caſes, diſtilled water would be an excellent ſubſtitute for Malvern Water, as the following experiment evinces.

Two

Vid. Dr. Wall's Treatiſe on Malvern water.

THESE few inſtances are ſufficient to ſhew the utility and importance of the following chemical enquiry into the nature and properties of the PUMP WATER of MANCHESTER. I ſhall therefore proceed to lay before the reader the moſt intereſting of my experiments on this ſubject, with ſuch remarks and obſervations as are obviouſly deducible from them.

EXPERI-

Two fragments of the ſame Calculus, nearly of equal weights, were immerſed, the one in three ounces of diſtilled water, the other in three ounces of hard pump water. The phials were hung up cloſe together, in a kitchen chimney, at a convenient diſtance from the fire. After fourteen days maceration, the calculi were taken out, and carefully dried by a very gentle heat. The former, viz. that which had been immerſed in diſtilled water, was diminiſhed in its weight a grain and half; the latter had loſt only half a grain.

EXPERIMENT I.

Near thirty different pump waters, moſt of them collected from pumps common to a whole neighbourhood, were chemically examined. They all curdled ſoap; the volatile alkali occaſioned a precipitation in many of them; the fixed alkali in all of them; and they became quite milky with a ſolution of *ſacharum ſaturni*. The infuſion of galls produced no change in their colour; but ſyrup of violets turned moſt of them green.

EXPERIMENT II.

A three ounce phial, after being carefully counterpoiſed in a very nice ballance, was filled to the brim with diſtilled pump water, which weighed twenty-one drachms and fifty grains. The ſame phial, exactly ballanced as before, was then filled to the brim with my own pump water, which weighed twenty-one drachms and fifty-ſix grains. Several other pump waters were examined in the ſame way, and very little difference was found in their ſpecific gravities. The water of a pump belonging to a public brewery in this place, weighed indeed, in the quantity above-mentioned, only twenty-one drachms and fifty-three grains. But on enquiry I learned, that this water is contained in a reſervoir, ſupplied by means of pipes, either from the rain which falls in the neighbouring grounds, or from the ſuperficial ſprings which run through them.

From the foregoing experiments it is obvious, that the pump water of Mancheſter is in general very impure. It is impregnated with a large quantity of ſelenite; an earthy, aſtringent ſalt, compoſed of the vitriolic, nitrous, or marine acid, and calcareous earth: And at the ſame time contains no inconſiderable proportion of alum, as the green colour which it ſtrikes with ſyrup of violets, clearly evinces (r).

(r) Dr. Lewis, whoſe accuracy is for the moſt part unqueſtionable, aſſerts in his *Materia Medica*, p. 71. "that the blue juices of vegetables are changed red by alum;" and again in his excellent notes on Neumann's Chemiſtry, p. 252. "that ſyrup of violets is changed red by waters impregnated with alum." This I apprehend is a miſtake; for in my tryals, two grains of alum diſſolved in an ounce of diſtilled water, ſtruck a pea green with twenty drops of the ſame ſyrup of violets, which was uſed in the above recited experiments. A tea-ſpoonful of lime water added to a part of the ſolution, conſiderably deepened the green colour; whereas two drops of elixir of vitriol produced in the other part a ſenſible, though faint redneſs. A ſolution of alum alſo in lime water was turned at once into a deep green, by the addition of a ſmall portion of ſyrup of violets. The lime water was added in the firſt experiment, to render the water employed more analogous to the hard, calcareous pump water of Mancheſter.

For were this effect owing to an alkaleſcent quality, ſalt of tartar, and eſpecially ſpirit of ſal ammoniac, would produce no precipitation in it. But what puts this concluſion beyond diſpute is, that an aluminous earth is frequently found in the wells of this town.—From the ſecond experiment it is evident, that a quart of water contains upwards of ſixty grains of adventitious

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In a later tryal I have found that the blue or purple juice of radiſhes is changed to a red, ſo ſlight however as barely to be perceptible, by a ſolution of alum in water. But this does not invalidate my concluſion, that many of the pump waters of Mancheſter are aluminous, becauſe they are turned green by an admixture of ſyrup of violets. For it appears, that a ſolution of alum produced a green colour in the ſame ſyrup of violets which was employed in the before-mentioned experiment. And to ſecure againſt all fallacy, I repeated that experiment ſeveral times. The reſult of it is alſo corroborated by the teſtimony of Neumann, who aſſerts, that the common ſorts of alum change the ſyrup of violets green. *Vid.* Neumann's Chemiſtry, p. 187.

ventitious matter; and ſuppoſing this quantity to be daily conſumed, in one way or other, by every individual, which is a moderate computation, about forty-ſix ounces troy weight, of crude, earthy, indigeſtible, and by no means inactive ſalts, will in the courſe of twelve months, be received into the body. And how pernicious this may be to health, thoſe can beſt conceive, who know the powerful influence of ſlight, but continued cauſes, on the human frame (f). I have not been reſident here a ſufficient length of time, to aſcertain with any degree of preciſion, the endemic diſeaſes of Mancheſter. But one obſervation, even a ſtranger hath it in his power to make, that the inhabitants of this place are peculiarly ſubject to glandular obſtructions, and ſcrophulous ſwellings. And that water loaded with aſtringent, earthy ſalts, hath a direct tendency to produce ſuch complaints, hath been already I hope fully evinced.

(f) *Quid magis eſt ſaxo durum? Quid mollius unda?*
Dura tamen molli ſaxa cavantur aqua. Ovid.

But hard and impure water may be conſidered in a further view as injurious to the human body. It was before obſerved, that this univerſal *menſtruum* is deſigned by nature to be the diluter, vehicle, and ſolvent both of our food, and of the recrementitious parts of the animal fluids. And in the performance of theſe ſalutary offices, it immediately promotes the general health of the body, and at the ſame time counteracts the influence of various cauſes of diſeaſe. The Spaniards, it is ſaid, are for the moſt part exempt from the itch and the ſcurvy, notwithſtanding they indulge themſelves in the daily uſe of pork, the leaſt perſpirable of all foods. And the reaſon aſſigned for this remarkable fact is, that the air of Spain is clear, thin, and ſerene, and the water light, pure, and wholeſome (t). Hence the minuteſt ſeries of veſſels are continued permeable and unobſtructed, perſpiration is free and copious, all the excretions are duly and regularly performed, and every thing putrid and acrimonious is carried out of the ſyſtem, before it has time to create diſturbance or diſorder. But water impregnated with auſtere, earthy, and indigeſtible ſalts, is ill qualified to anſwer theſe important ends. Already nearly ſaturated with its heterogeneous contents, it is rendered leſs capable of diſſolving our food, of mingling uniformly with our fluids, of penetrating the fineſt ramifications of the vaſcular ſyſtem, and of paſſing off copiouſly and eaſily by the ſeveral emunctories. And thus it becomes negatively the cauſe of diſeaſes.

(t) *Vid.* Hoffmanni Opera, Tom. 6. p. 204. ---- Herodotus, whoſe teſtimony is not always to be depended upon, relates that in Æthiopia the inhabitants live to be an hundred and twenty years old, that they eat fleſh, and drink milk; that the water of the country is ſo light, that nothing will float upon it, not even wood, and that the uſe of this water makes them long lived. Lib. 3. c. 125.

It is therefore of the utmoſt conſequence, where nature hath denied the benefit of pure water, to diſcover ſome means of correcting its pernicious qualities. And with this view the following experiments were made.

EXPERIMENT III.

A ſtrong ſolution of ſalt of tartar was inſtilled into hard pump water, till no lacteſcency enſued. The ſame experiment was repeated with a ſmaller quantity of *ſal tartari*, ſo as not to deſtroy the inſipidity of the water; but the ſoftening effect of the vegetable alkali, was then ſcarcely perceptible. Hence it appears that the Mancheſter pump waters, are too hard to be much improved in this way, without rendering them offenſive to the palate.

EXPERIMENT IV.

To half an ounce of hard pump water, juſt boiled, were added five drops of a ſolution of *ſacharum ſaturni.* To an equal quantity of the ſame water unboiled, were alſo added five drops. The boiled became much leſs milky than the cold water. But ſuppoſing this effect to ariſe from the heat of the water, I poured half an ounce of it into a glaſs, and when cold, inſtilled five drops of the ſolution of ſugar of lead into it as before, without any increaſe of its lacteſcency. I then took equal quantities, viz. half an ounce of unboiled water, and of water which had been boiled over a briſk fire during the ſpace of twenty minutes, and poured into each a few drops of the ſolution of *ſacharum ſaturni.* The raw water became twice as milky as the boiled water, and depoſited a much larger ſediment. And I thought the water which had been boiled twenty minutes, was leſs changed by the addition of ſugar of lead, than that which had undergone only a ſlight coction. Ten drops of *ſp. ſal. ammon. vol.* added to half an ounce of raw ſpring water, turned it milky; but when added to an equal quantity of the ſame water which had been boiled twenty minutes, no change was produced. Three grains of fixed alkali, *(ſal tartari)* diſſolved in half an ounce of the ſame boiled water, occaſioned no ſenſible cloudineſs; but when mixed with an equal quantity of raw water, a great lacteſcency and copious precipitation immediately enſued. The boiled water ſtill continued to break and curdle with ſoap, though in a leſs degree than the ſame water unboiled. The former alſo felt to the touch much ſofter than the latter.

THIS experiment clearly demonſtrates, that hard water is freed from ſome of its earthy ſalts, and rendered conſiderably ſofter by boiling. And it appears likewiſe, that the coction ſhould be continued ſome time, in order to produce its full effect. Dr. Heberden is indeed of a contrary opinion; for notwithſtanding he acknowledges, that the unneutralized lime-ſtone and ſelenite is ſeparated by boiling from pump water, yet he thinks it becomes more ſtrongly impregnated with the ſaline matter, and conſequently leſs ſalutary. But the Dr. ſeems to have derived his opinion, not from experiment, but from miſtaken theory. For though heat generally increaſes the diſſolving power of any *menſtruum*, at the ſame time it tends, in many inſtances, to deſtroy the texture, and diſunite the component parts of the ſolvend. Thus hot water ſuſpends a much larger quantity of nitre than cold water; but if the ſolution be boiled over the fire, a conſiderable portion of the ſalt-petre will be diſſipated. If then the nitrous acid be volatilized and ſeparated from its alkali by coction, may we not juſtly infer, that it will be diſengaged by the ſame cauſe from an earthy baſis, to which it bears comparatively but a weak affinity? And the ſame reaſoning may be applied with equal force to the volatile vitriolic or muriatic acids, which in all probability fly off by means of the boiling heat, leaving behind them an indiſſoluble, petrifying earth, that ſubſides to the bottom, and incruſts the veſſel.

EXPERIMENT V.

A quantity of hard pump water, which had paſſed through a filtering ſtone, when compared with the ſame water unfiltered, was found to be conſiderably ſoftened. Each curdled with ſoap, but the former in a leſs degree than the latter: The volatile alkali occaſioned no cloudineſs in the filtered water, but a viſible one in the other: The fixed alkali produced a precipitation in both, leſs however in the former, than in the latter; and the ſolution of *ſacharum ſaturni* rendered the unfiltered water much more lacteſcent, than that which had ſoaked through the filtering ſtone.

THESE two experiments point out an eaſy and obvious method of purifying hard water, by freeing it in ſome meaſure, from the unneutralized ſelenite, and groſſer ſalts which it contains.

tains. The water ſhould firſt be boiled for the ſpace of fifteen or twenty minutes, then paſſed through the filtering ſtone; and thus it will be rendered tolerably pure, ſalutary and potable, and at the ſame time much better adapted to a variety of culinary uſes.

EXPERIMENT VI.

MR. Boyle aſſerts that ſome pump waters, barely by ſtanding a few days, will become ſoft enough to mix uniformly with ſoap (u). A quantity of hard pump water was therefore expoſed to the ſun and air, but ſo as to be ſheltered from the rain, for the ſpace of a week. It curdled with ſoap, and became as milky with a few drops of ſugar of lead, as water juſt drawn from the well. The volatile alkali indeed, produced no cloudineſs in it, and this was the only mark which it afforded of being in the leaſt degree ſoftened.

(u) Boyle's Works, Shaw's Edit. Vol. 1. p. 141.

EXPERIMENT VII.

A ſtrong infuſion of malt was not more miſcible with ſoap, than the boiled water with which it was prepared; nor did it ſuffer a leſs precipitation on the addition of a few grains of *ſacharum ſaturni.*

EXPERIMENT VIII.

STRONG table beer, drawn from the barrel about ten days after it had been brewed, curdled with ſoap as much as the hard water boiled, which was employed in its preparation.

HENCE it appears that fermentation hath not the power of ſoftening hard water; and that the wholeſomeneſs of malt liquors, muſt greatly depend upon the purity of the water which is uſed in brewing them. This coincides with the following obſervation of Hoffman: *Bonitas cereviſiarum primò à ſalubri aqua dependet. Quo ſalubrior aqua fontana eſt, eo præſtantiorem exhibet cereviſiam ; & quo ſubtilior aqua, eo plus ingredientia extrahit, eoque melius fermenteſcit* (x).

EXPERIMENT IX.

STRONG infuſions of green and bohea tea in boiled hard water, curdled with ſoap, and were as much changed by the addition of ſugar of lead, as the boiled water itſelf. So that theſe faſhionable and favourite articles of diet, notwithſtanding the ſoft taſte which they communicate to the hardeſt water, do not really alter or improve its nature. It were well however,

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(x) Hoffman. Op. Vol. 1. p. 113.

ever, if tea could be conſidered in this reſpect merely as innocent or uſeleſs; but it imparts many pernicious qualities to its aqueous *menſtruum*; and the daily uſe of it, by inſenſible degrees enfeebles the conſtitution, and brings on a train of nervous diſorders.

EXPERIMENT X.

Two or three pieces of common brick were ſteeped four days, in a baſon full of diſtilled water. The water was then decanted off, and examined by various chemical teſts. It was immiſcible with ſoap, ſtruck a lively green with ſyrup of violets, was rendered ſlightly lacteſcent by the volatile alkali, and quite milky by the fixed alkali, and by a ſolution of *ſacharum ſaturni*. The infuſion of tormentil root produced no change in it.

EXPERIMENT XI.

An experiment ſimilar to the former was tried with a rough piece of free-ſtone, *(ſaxum arenarium)* which did not appear to have communicated any impregnation to a baſon full of diſtilled water, in which it had been ſeveral days immerſed.

The 10th experiment affords a ſtriking proof of the impropriety of lining wells with brick, a practice very common in many places, and which cannot fail of rendering the water hard and unwholeſome. Clay generally contains a variety of heterogeneous matters. The coloured loams often participate of bitumen, and the ocher of iron: Sand and calcareous earth are ſtill more common ingredients in their compoſition; and the experiments of Mr. Geoffroy and Mr. Pott prove, that the earth of alum alſo, may in large quantity be extracted from them. Now as clay is expoſed to the open air for a long ſpace of time, is then moulded into bricks, and burnt, this proceſs reſembles in many reſpects that by which the alum-ſtone is prepared. And it is probable, that the white efforeſcence, which is frequently obſervable on the ſurface of new bricks, is of an aluminous nature (y).

It hath long been a prevailing opinion, that water flowing through leaden pipes, acquires certain noxious qualities. Hippocrates, and his commentator

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(y) The long expoſure of clay to the air, before it is moulded into bricks, the ſulphureous exhalations of the pit coal uſed in burning it, together with the ſuffocating and bituminous vapour which ariſes from the ignited clay itſelf, ſufficiently account for the combination of a vitriolic acid with the earth of alum.

tator Galen, expreſsly condemn the uſe of ſuch water; and Vitruvius in his treatiſe on Architecture, remonſtrates ſtrongly againſt that means of conveying water. *Multo ſalubrior ex tubulis aqua quam per fiſtulas: quod per plumbum videtur eſſe ideo vitioſa, quod ex eo ceruſſa naſcitur: hæc autem dicitur nocens eſſe corporibus humanis. Itaque minimè fiſtulis plumbeis aqua duci videtur, ſi volumus eam habere ſalubrem* (z). Neumann, whoſe authority as a chemiſt is of great weight, gives it as his opinion, that the waters conveyed by pipes may corrode ſome of the matter of the pipe or of its cement, and thus contract diſagreeable qualities. And he aſſures us, that having examined the aquæducts at Rome, thoſe between Marly and Verſailles in France, and thoſe by which London is ſupplied with the New-river water, he found them in ſome places liable to this inconvenience (a). But a celebrated writer, who has lately favoured the publick with an excellent treatiſe on the poiſon of lead, thinks the caution of Vitruvius and of Galen unneceſſary, except in ſuch caſes where a quantity of vegetable acid might be ſuppoſed to render the metal diſſoluble in water (b). I cannot however agree with him in this opinion, notwithſtanding his experiments at firſt ſight appear to be ſo concluſive. For I apprehend the water he employed in his tryals, either contained no acid, or that the acid was combined with other ſubſtances, by which it was more powerfully attracted than by lead. This metal diſſolves very readily in weak *aqua fortis*, or in oil of vitriol well diluted with water (c). And from Dr. Cullen's table of Elective Attractions it appears, that the laſt of theſe acids has a much ſtronger affinity with lead, than with the earthy baſis of alum. As ſpring waters are therefore ſo frequently found to be aluminous, may we not with reaſon ſuſpect, that in their paſſage through leaden pipes, the vitriolic acid will depoſit the earth with which it was combined, and diſſolve ſome portion of the metal. And thus the fountain will become impregnated with a metallic ſalt, of the moſt poiſonous and deleterious quality. It is a common obſervation that hard water renders pewter black; and this in all probability ariſes from a ſolution of the lead and tin, of which this mixed metal is compoſed. But as a point of ſo much importance to the health of mankind, ought to reſt on better evidence than theoretical reaſoning, the following experiment was made in order to determine, whether water impregnated with alum be capable of diſſolving lead.

(z) Vitruvius, lib. 8. c. 7.

(a) Neumann's Chem. by Lewis, p. 248.

(b) *Vid.* Medical Tranſactions, No. 13.

(c) Shaw's Notes to Boerhaave's Chem. Vol. 1. p. 85.

EXPERIMENT XII.

Two clean and bright bits of lead, weighing 327 grains were immerſed ſixteen days in a phial of water, in which a drachm of alum had been previouſly diſſolved. The volatile tincture of ſulphur produced no blackneſs in this water, until a few drops of the ſolution of *ſacharum ſaturni* were added to it, and then a duſky colour immediately ſucceeded. The bits of lead carefully wiped and dried, were not found to have ſuffered any ſenſible loſs of weight.

The ſame experiment was repeated with hard, aluminous pump water. I conceived, that the lead had communicated ſomewhat of a ſweetiſh taſte to the water; but when a few drops of the volatile tincture of ſulphur were inſtilled into it, it did not exhibit any appearance of a ſaturnine impregnation: Nor had the bits of lead loſt any part of their weight.

THOUGH the reſult of this experiment ſeems to overturn the theory before advanced, yet it does not afford me full conviction, that lead is totally inſoluble in aluminous waters. For the volatile tincture of ſulphur may not perhaps, in every inſtance, be a certain teſt of the preſence of this poiſonous metal, as I have elſewhere proved, that green vitriol is not of the aſtringency of vegetables (d). But conſcious of the influence of a preconceived hypotheſis, I have fairly ſtated both the reaſons and facts, relating to this point, and ſhall leave the deciſion concerning them to the more unbiaſſed judgment of the reader. The uſe of leaden pumps however may be pernicious, though the conveyance of water through pipes of this metal ſhould not be eſteemed ſo: For by the friction of the bucket againſt the ſides of the pump, ſome portion of lead will be rubbed off, and ſuſpended in the water (e).

(d) Eſſays Medical and Experimental, p. 137.

(e) Though it be foreign to my preſent ſubject, I cannot omit this opportunity of cautioning againſt the practice of cleaning wine bottles with leaden ſhot. It frequently happens, I am perſuaded, through the careleſsneſs of ſervants, that ſome of the little pellets are left behind; and when wine or beer is again poured into the bottles, this mineral poiſon will ſlowly diſſolve, and impregnate thoſe vinous liquors with its deleterious qualities. The ſweetneſs which is ſometimes perceived in red port wine, may ariſe from this cauſe, where ſuch an adulteration is neither deſigned nor ſuſpected.

SECTION II.

FROM the ſubject of this experimental enquiry into the different properties of hard and ſoft water, we are naturally led to conſider their influence on many of the operations of PHARMACY. And we ſhall find, that the moſt innocent vehicle, is alſo the moſt powerful *menſtruum* for extracting the virtues of medicines.

EXPERIMENT XIII.

Two drachms of green tea, were ſeparately macerated without heat, an equal length of time, the one in three ounces of hard pump water, and the other in the ſame quantity of diſtilled water. The latter infuſion had a more bitter taſte, and ſtruck a much deeper black than the former, with three grains of *ſal martis*.

EXPERIMENT XIV.

A drachm of bark finely powdered, was macerated two days, without heat, in three ounces of diſtilled water; and the ſame quantity, during the ſame ſpace of time, in three ounces of hard pump water. The infuſion made with diſtilled water, was of a paler colour than the other, but yet taſted more intenſely bitter, although ſomewhat leſs rough and ſtyptic. Two grains of *ſal martis* were added to half an ounce of each infuſion, carefully filtered. The latter ſtruck a much deeper black than the former.

Disappointed in the reſult of this experiment, I repeated it again, but with nearly the ſame ſucceſs as before. Twenty drops of a ſtrong ſolution of *ſal martis*, produced at firſt no ſenſible change in half an ounce of the infuſion made with diſtilled water, whilſt the ſame number of drops, almoſt inſtantly ſtruck an inky blackneſs with the other infuſion, prepared with hard pump water. By degrees indeed the former aſſumed a duſky hue, but after ſtanding many hours, did not half equal the blackneſs of the latter.

EXPERIMENT XV.

THIRTY drops of a ſolution of alum in lime water were inſtilled into half an ounce of the infuſion of bark, made with diſtilled water. By this addition the ſame quantity of *ſal martis* employed in the laſt experiment, immediately produced a very duſky colour; and in leſs than an hour, the mixture aſſumed an inky blackneſs.

EXPERIMENT XVI.

Two drachms of tormentil root bruiſed, were macerated in equal quantities,

tities, viz. three ounces of hard pump water, and of diſtilled water, during the ſpace of twenty-four hours. The latter infuſion was of a deeper orange colour, than the former, and had a rougher and more ſtyptic taſte. But when twenty drops of a ſolution of *ſal martis* were added to equal portions of each infuſion, an inky blackneſs, to all appearance preciſely the ſame, enſued in both.

EXPERIMENT XVII.

An experiment ſimilar to the former was tried with aleppo galls, by macerating two drachms of their powder in equal quantities of hard pump water, and of diſtilled water: but the reſult was ſomewhat different. I could not by comparing their taſtes, determine which infuſion was moſt aſtringent or ſtyptic. That made with diſtilled water was of a paler colour than the other; yet it ſtruck a much deeper black with green vitriol.

EXPERIMENT XVIII.

Equal quantities of peruvian bark powdered, were macerated without heat forty-eight hours, in three ounces of hard pump water, and of the ſame pump water boiled. The latter infuſion had a ſtronger taſte of the *cortex*, but did not ſtrike ſo deep a black with the ſolution of *ſal martis*.

From theſe experiments it may be inferred that ſoft water, and eſpecially diſtilled water, acts far more powerfully as a *menſtruum* on vegetable bitters and aſtringents, than hard pump water. And the concluſion may in all probability, be extended to many other claſſes of vegetables. The fourteenth experiment indeed, ſeems at firſt view to prove that the peruvian bark yields its aſtringency more perfectly to hard, than to ſoft water; but the ſucceeding experiment ſhews the fallacy of this inference. For the addition of thirty drops of a ſolution of alum in lime water, could not give any real increaſe to the ſtrength of an infuſion of the *cortex*, previouſly prepared; although it enabled it to ſtrike a deeper black with green vitriol. But from this curious fact we may conclude, that hard, aluminous waters are likely to anſwer beſt in the dying of black; and this is confirmed by the obſervation of Dr. Lewis, that alum heightens the colour of the watery tinctures of madder and brazil (f).

It is found that hard, calcareous waters render the mixture of reſinous bodies, by the intervention of mucilage of gum arabic, difficult and ſometimes

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(f) *Vid.* Neumann's Chem. by Lewis, p. 187.

times impracticable (g). This naturally led me to conceive, that ſoft, or diſtilled water, might poſſibly diſſolve thoſe ſubſtances without the aſſiſtance of any medium, or at leaſt with a much ſmaller proportion of gum, than is commonly employed. On ſuggeſting this hint to a ſenſible and ingenious apothecary of this place, he very obligingly undertook to make the experiments for me, and has ſent me the following account of the reſult of them, which I ſhall deliver in his own words. The letter contains ſome further tryals, which do not relate to the preſent ſubject; but as they lead to ſeveral uſeful and important concluſions, I ſhall without any apology inſert them.

(g) *Vid.* Lond. Med. Obſerv. Vol. 1. p. 435.

I cannot avoid remarking a miſtake into which the learned and accurate Dr. Fothergill hath fallen, in the uſeful paper here referred to, by not varying the circumſtances of his experiment. He obſerves, that volatile alkalies prevent the union of oil and water, by the intervention of mucilage; and ſuppoſes this effect to ariſe from the latent acid of the gum being deſtroyed by the alkali. Whether gum arabic contains any acid is, I ſhould apprehend, very dubious; but I am well aſſured, from repeated tryals which different apothecaries have made for me, that an uniform and neat compoſition may be produced in the following manner.

℞ *Ol. oliv. vel ſperm. ceti.---mucilag. g. arab. tere ſimul in mortario, dein adde, alk. vol.---denuo tere & paulatim adjice, aq. ſimp.---ſpirit.---ſyrup. M.*

The combination of the volatile alkali with oil or ſpermaceti, is of conſiderable importance in many diſorders of the breaſt.

Mancheſter, June 29, 1768.

DEAR SIR,

I Have made the experiments you deſired of diſſolving reſinous ſubſtances in diſtilled and common pump water, the reſult of which ſeems to be much in favour of the former.

One ſcruple of balſam of tolu rubbed with half an ounce of diſtilled rain water, added gradually to it, for fifteen minutes, formed a mixture, which on ſtanding about a minute ſubſided, but reunited by ſhaking: being ſet by a few days, the balſam became a concrete maſs, not again miſcible by ſhaking up the bottle.

The ſame quantity required more trituration to mix it with common pump water. The mixture was not kept.

One ſcruple of the ſame, rubbed with fifteen grains of gum arabic, was nearly as long in perfectly uniting with half an ounce of diſtilled water as that without the gum. This was perhaps owing to the latter piece being more reſinous; however, though on long ſtanding there was a ſmall ſediment, it immediately reunited a week after by agitation.

FIFTEEN grains of balſam capivi united very ſmoothly with diſtilled water half an ounce, by the medium of three grains of gum arabic—Five grains of the gum were not ſo effectual with pump water.

BALSAM peru ten drops, with gum arabic ten grains, diſtilled water half an ounce, formed a neat white emulſion, but with common water a very unequal mixture.

GUM myrrh powdered, that there might be no difference in the ſeveral quantities uſed, half a ſcruple, diſſolved readily with gum arabic three grains, in both kinds of water, and even mixed with them by longer trituration without any medium, but more eaſily with diſtilled than common ſpring water. Olibanum, maſtick, gum guaiacum, and galbanum may likewiſe be mixed with water by rubbing, without any gum arabic or egg.

The ſpring water which was made uſe of was from my own pump, and is very aluminous.

The ſolution of crude mercury with mucilage of gum arabic being ſo eaſily accompliſhed, and it being very diſagreeable to many patients, and to ſome almoſt impoſſible to ſwallow pills, boluſſes, or electuaries; I was induced to try whether calomel, cinnabar, and the other heavy and metalline bodies commonly adminiſtered only under theſe forms, might not by the ſame means be rendered miſcible with water, ſo as to be given more agreeably in a liquid form.—I had indeed ſometimes ſeen injections made with calomel and gum arabic, but had not obſerved whether it ſuſpended the calomel ſo uniformly as to be given by the mouth.

I accordingly rubbed ten grains of cinnabar of antimony and a ſcruple of gum arabic with a ſufficient quantity of diſtilled water to form a mucilage, and added a drachm of ſimple ſyrup, and three drachms more of water.

THIS makes an agreeable little draught, and having ſtood above half an hour without depoſiting any ſediment, I added three drachms more of water to it, and notwithſtanding the mucilage was rendered ſo much more dilute, very little of the cinnabar ſubſided even after it had ſtood ſome days.

STEEL ſimply prepared, and prepared tin were both mixed with water by their own weight of gum arabic, and remained ſuſpended, except a very ſmall portion of each, which was not reduced to a ſufficiently fine powder.

FIVE grains of calomel were mixed with two drachms of diſtilled water and half a drachm of ſimple ſyrup, by means of five grains of gum arabic, which keep it ſufficiently ſuſpended, a double quantity of the gum preſerved the mixture uniform ſtill longer. In this form it will be much more eaſily given to children, than in ſyrups, conſerves, &c. as a great part of it is generally waſted, in forcing thoſe viſcid vehicles into them, and it may be joined with ſcammony and other reſinous purgatives by the ſame method, and of theſe perhaps the gum arabic would be the beſt corrector.

Gum arabic likewiſe greatly abates the diſagreeable taſte of the corroſive ſublimate, mixed with water inſtead of brandy, and (from the few tryals I have made) ſits eaſier on the ſtomach, and will not be ſo apt to betray the patient by the ſmell of the brandy.

Mr. Plenck, who firſt inſtructed us in the method of mixing quick-ſilver with mucilage, obſerves, (and experience confirms the truth of it) that this preparation is not ſo apt to bring on a ſpitting as the *argent. viv.* mixed by any other medium, or as the ſaline and other mercurial preparations.—How far the theory by which he accounts for it may be juſt, is not of much importance, but it may perhaps be worth while to enquire whether it would not be equally effectual in preventing calomel, and the other preparations of mercury, from affecting the mouth.—If ſo, is it not improper where a ſalivation is intended, to give emulſions with gum arabic and other mucilaginous liquors for the patient's common drink, as by that means the ſpitting may be retarded? And on the contrary, may it not be a uſeful medicine to diminiſh the diſcharge when too copious (h)?

BUT—

(h) The following caſe may in ſome meaſure ſerve to confirm the above obſervation.

A Gentleman, always eaſily affected by mercurials, having taken about twenty-ſix grains of calomel in doſes from one to three grains, notwithſtanding he was purged every third day, was ſuddenly ſeized with a ſalivation. He ſpat plentifully, his breath was very fœtid, teeth looſe, and his gums, fauces, and the margin

But—*Ne ſutor ultra crepidam.* And though I am ſure your friendly candour will excuſe theſe trifling obſervations, which have occurred as I was writing, yet I fear I treſpaſs upon

I time

margin of his tongue greatly ulcerated and inflamed. He was directed to uſe the following gargle.

℞ *Gum. arab. ſemiunc. ſolve in aquâ font. bullient- ſelib. & adde mel. roſac. unc. unam. M. ſt. gargar.*

And to drink freely of a ptiſan prepared with *aq. hord. lib. ij. gum. arabic. unc. ij. nitr. pur. drachm. ij. ſacchar. alb. unc. j.*

His purgative was repeated the ſucceeding morning.

The next day his gums were leſs inflamed; but the ſloughs on his tongue, &c. were ſtill as foul; his ſpitting was much the ſame: he had drank about a pint of the ptiſan.---Some *ſpt. vitrioli* was added to the gargle.

From this day to the fourth, he was purged every day without effect---his ſalivation ſtill continued, his mouth was no better---he had neglected the mucilaginous drink---this evening he was perſuaded to drink

about

time which you would ſpend much more uſefully, than in peruſing theſe indigeſted thoughts of, dear Sir,

Your very obliged and humble Servant,

THOMAS HENRY.

EXPERIMENT XIX.

IT has been remarked by Dr. Whytt, and many others, that different kinds of quick lime impregnate water with different degrees of ſtrength. This ſuggeſted

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about a pint of it which remained, and he had it repeated, and drank very freely of it that night.

On the fifth morning the purgative was again repeated. Though it operated very little, yet the change was very ſurpriſing, his mouth was nearly well, and his ptyaliſm greatly decreaſed---the ptiſan was repeated, and on the ſixth day being quite well, he was permitted to go abroad.

See alſo Dr. Saunders's appendix to the ſecond edition of Mr. Plenck's treatiſe, ſince publiſhed.

ſuggeſted to me that a diverſity in the *menſtruum*, may alſo conſiderably vary the qualities of the lime water. And my conjecture has been confirmed by the enſuing experiment.

Equal quantities, viz. a quart, of diſtilled water, of boiled pump water grown cold, and of the ſame hard pump water unboiled, were ſeverally added to half a pound of quick-lime. After an infuſion of twenty-four hours, the waters were decanted off, and filtered through paper. Ten drops of ſyrup of violets ſtruck a deep green with the lime water, made with diſtilled water, a lighter one with that prepared with boiled water, and the lighteſt with the raw pump water. Sixty drops of a ſolution of ſalt of tartar in diſtilled water, added to each lime water in the foregoing order, occaſioned the largeſt precipitation from the firſt, the next in degree from the ſecond, and the leaſt from the third. The taſtes of the different lime waters correſponded alſo with the above-mentioned teſts. For that made with diſtilled water was by far the moſt pungent, and yet the leaſt diſagreeable; whereas that prepared with raw pump water, was extremely harſh and nauſeous, without being proportionably impregnated with the acrimony of the quick-lime.

EXPERIMENT XX.

THREE fragments of human *calculi*, numbered for the ſake of diſtinction, 1, 2, 3, were immerſed in equal quantities of different lime waters; the firſt in lime water made with diſtilled water, the ſecond in lime water prepared with hard pump water, and the third in lime water made with the ſame hard pump water poured boiling hot upon the quick-lime. No. 1, was of a brown colour, and hard texture, was ſmooth on one ſide and rough on the other, and weighed twenty-ſix grains and a half. No. 2, was a fragment of the ſame *calculus*, and weighed twenty-five grains and a half. No. 3, a fragment of a different *calculus*, was of a looſer and more ſpongy texture than the former, and weighed twenty-ſeven grains. The phials which contained the *calculi* and four ounces by meaſure of lime water, were all nearly full, and cloſely corked up. After continuing the maceration eight days without heat, the *calculi* were taken out, carefully dried on filtering paper before a gentle fire, and then weighed. No. 1, had loſt a grain and half, and was covered over in many parts of it with a ſoft, white, cretaceous matter. No. 2, had loſt only half a grain: Many little cryſtals ſhot from its ſurface. No.

3, had loſt a grain. But it ſhould be remembered, that this fragment was much ſofter than the other two. The lime employed in this experiment was common ſtone quick-lime; that uſed in the former experiment, was brought out of Derbyſhire, and made of a ſpecies of marble containing a great many ſhells in its ſubſtance. I was not aware of the difference of the lime, 'till after my tryals were completed.

THESE two experiments, I think, ſatisfactorily prove, that ſoft water is a much more powerful diſſolvent of quick-lime, than hard water (i), at the ſame time that it covers and meliorates the harſh taſte of that acrid ſubſtance. Where diſtilled water cannot conveniently be provided, rain water, freed by filtration from its impurities, may with equal efficacy be ſubſtituted in its room. Had a different kind of lime been employed in the laſt experiment, or had the digeſtion been made in a ſand bath, it is probable the ſolvent power of each *menſtruum* would have been encreaſed. The little pointed cryſtallizations, which were obſerved to ſhoot from the fragment of *calculus* No. 2, remind me of a ſimilar appearance which occurred in one of the tryals of the late Dr. Whytt, and which he informs us ſurprized him greatly. He aſcribes them to the ſea ſalt adhering, even after calcination, to the oyſter-ſhells which he employed (k). But the Doctor muſt have been miſtaken in his explanation, as in the experiment juſt recited, common ſtone quick-lime alone was uſed, which cannot be ſuppoſed to contain any ſea ſalt. And the cryſtallizations were perceived only in that phial of lime water, which had been prepared with hard pump water.

(i) To aſcertain more fully this important point, I have ſince repeated the experiment above recited, by immerſing again the fragments of the ſame calculus, Nos. 1 and 2, in equal quantities of freſh lime water, prepared with diſtilled water, and with hard pump water. In twelve days, No. 1, was entirely reduced to a chalky powder, whilſt No. 2, preſerved its texture, to all appearance unchanged.

(k) Whytt's Eſſay on Lime Water, 3d Edition, p. 74.

SECTION III.

A comparative view of the different properties of SNOW WATER, RAIN WATER, SPRING WATER, &c.

SNOW WATER: This is ſaid by Mr. Boyle to be the lighteſt of all waters; and if received upon the tops of high mountains muſt, one ſhould conceive, be free from all foreign impregnation. And yet the ſame accurate chemiſt found on examination, that it is not entirely deſtitute of ſaltneſs. But notwithſtanding the ſuperior purity of ſnow water, I ſhould apprehend, that it is not the moſt wholeſome liquor for common drink, becauſe its properties as a *menſtruum* are changed by the congelation it hath undergone. For freezing certainly decompoſes water, by ſeparating from it a conſiderable portion of its fixed air. And that this alters its qualities is evident from the following facts. 1. Water when freſh, diſſolves a larger quantity of ſalt, than when exhauſted of its air. 2. Water ſaturated with any ſalt, when placed *in vacuo* under the receiver of an air pump, will depoſit part of its ſolvend. 3. Snow water is obſerved not to boil greens or peaſe ſo well as common water. 4. The nitrous acid generates a much leſs degree of heat with ſnow water, than with common water. Hippocrates utterly condemns the uſe of ſnow or ice water, becauſe after congelation it never re-aſſumes its former nature; the clear, light, and ſweet part of it being diſſipated, whilſt the moſt turbid and heavy is left behind. And he adduces an experiment in ſupport of this reaſoning. Expoſe, ſays he, a veſſel containing a certain quantity of water to the cold air in winter time, ſo as that it may be frozen hard; then bring it into a warm place, where it may thaw; and when the ice is diſſolved, meaſure the water again and you will find it evidently diminiſhed. But this loſs of bulk is not as Hippocrates ſuppoſes, to be aſcribed to the diſſipation of the thinner and finer parts of the water by congelation, but chiefly to the ſeparation of the fixed air it contained; and therefore his reaſon for condemning the uſe of ſnow water is founded on a falſe hypotheſis. This however does not invalidate his objection to it, which he at firſt, in all probability, deduced from experience, and afterwards attempted to explain and confirm, by what now appears to be miſtaken theory.

ICE WATER: What has been ſaid of ſnow water is equally applicable to ice water, except that its ſpecific gravity is greater, and that it is leſs free from ſaline impregnation, and conſequently ſtill leſs ſalubrious.

Rain Water, when collected in clean veſſels, at a diſtance from large towns, is light, ſoft, and wholeſome. But as it paſſes through the atmoſphere, which is a chaos of different exhalations from the animal, vegetable, and mineral kingdoms, it muſt waſh down ſome of thoſe floating, volatile particles, and be impregnated with them. Hence rain will differ in ſome ſlight degree, according to the ſeaſon of the year, as well as the country in which it falls. That it contains a quantity of adventitious matter is evident from its tendency to putrefy, from the green weed which ſprings up on its ſurface, and from the mucilaginous or ropy ſubſtance which grows copiouſly on it, and which Boerhaave compares, on viewing it through a microſcope, to a grove of little muſhrooms. It is obſerved alſo, after ſtanding a while, to be full of the *ovula* of different animalcules: ſome of which may have been carried down with it, in its paſſage through the air, but the greater number are probably depoſited in it, during its ſtagnation. But although theſe circumſtances prove, that rain water is by no means an homogeneous fluid, or free from impurity, yet it is univerſally acknowledged to be the moſt ſalutary of all other kinds of water. And by percolation through ſand or ſtone, or by boiling and decanting, its foulneſs would in a great meaſure be ſeparated, and it would be rendered a grateful, potable, and very wholeſome liquor. Its levity is ſo great, that diſtilled rain water is not lighter than the natural, as Boerhaave affirms after weighing them in the hydroſtatical ballance. Nor need we wonder at this, as the exhalation of aqueous vapours from the earth and ſea, is exactly analogous to diſtillation; if it be not an impropriety to compare the vaſt and ſtupendous operations of nature, with the trifling efforts of art. Hippocrates gives his teſtimony in favour of rain water, but directs that it ſhould be boiled or ſtrained; otherwiſe it has an ill ſmell, and occaſions a hoarſeneſs, and deep voice in thoſe who drink it (l).

SPRING WATER: This muſt vary in its properties according to the nature of the ſoil, and the different ſtrata of earth, through which it paſſes. The pureſt is that which flows, at no great depth, through a light gravel, or ſand. Dr. Hales mentions ſeveral ſprings, remarkable for their levity, and freedom from calcareous impregnation.

(l) Hippoc. *de Aere, Aquis et Locis.*

The water, conveyed by pipes to Hodſon in Hertfordſhire, which riſes from a gravel, and guſhes out of a fine white ſand, he informs us, left no incruſtation in a boiler, which had been uſed fifteen years. And that of Comb in Surrey, a hill, the ſoil of which is gravel almoſt to the ſurface, is alſo uncommonly light, ſoft and free from all adventitious ingredients. As the ſprings iſſue from the brow of the hill, out of the gravel, the Dr. juſtly obſerves, that the water muſt partake greatly of the nature of rain water; ſince the dew and rain which fall on that hill, receive probably no other alteration from percolating through the gravel, than that of being rendered more pure and free from foulneſs (m). Hippocrates lays a great ſtreſs upon the choice of ſprings, which have an eaſtern aſpect. Such waters, he ſays, are chiefly to be commended, that guſh out towards the riſing of the ſun; becauſe they are clearer, lighter, and of a better ſmell than others. But I apprehend there is no foundation for this opinion of the father of phyſick. For water which flows through clay, marle, black mould, or beds of minerals, will be equally hard and unwholeſome in whatever expoſure it firſt burſts out. The purity and ſalubrity of it may however, with ſufficient accuracy be aſcertained, by its levity, tranſparency, and perfect inſipidity; by its mingling uniformly with ſoap, and boiling pulſe tender. And theſe are common teſts, which it is in the power of every one to apply.

(m) *Vid.* Statical Eſſays, Vol. 2. p. 242.

RIVER WATER: This is generally much ſofter, and better adapted to œconomical uſes than moſt ſpring water. For though rivers proceed originally from ſprings, yet by their rapid motion, and by being expoſed during a long courſe, to the influence of the ſun and air, the earthy and metallic ſalts which they contain are in part decompoſed, the volatile acid flies off, and the terreſtrial or ochery particles with which it was combined, become inſoluble and are precipitated. To this it may be added, that rivers are alſo rendered ſofter by the vaſt quantity of rain water, which paſſing along the ſurface of the earth, is immediately conveyed into their channels. But all rivers carry with them, a great deal of mud, filth, and other impurities. And when they flow near large, populous, and manufacturing towns, they become the receptacles of all the common ſewers, and are impregnated with an heterogeneous mixture of coperas, alum, ſoap lyes, logwood, and the refuſe of a thouſand other ſubſtances, employed in different arts. In this ſtate, river water is certainly unfit for the common purpoſes of life. And yet if it be ſuffered to remain a while at reſt, all the feculencies will ſubſide, and the water will become ſufficiently pure grateful, and potable.

STAGNANT WATERS: Theſe of all others are the moſt impure and inſalubrious. Hippocrates aſſerts, that they enlarge and obſtruct the ſpleen; and his obſervation is almoſt daily confirmed, by the diſſection of thoſe who die of the ſcurvy; a diſeaſe which putrid, ſtagnant water hath a powerful tendency to produce. Dr. Hoffman, by means of a glaſs water poiſe divided by lines, examined hydroſtatically ſeveral different kinds of water. Rain water he found the lighteſt; river water was one line heavier; the water commonly uſed at Hall, in Saxony, was heavier by two lines; the ſpring water of the ſame place was four lines heavier; that of a particular ſpring was ſix lines heavier; and water which had been long kept in an open veſſel, in a cellar, was ſix lines and a half; but ſtagnant water, drawn out of the town ditch at Hall, was ſeven lines heavier than rain water (n).

I ſhall conclude this Eſſay with the following obſervations of Celſus, which in many reſpects coincide with what has been advanced. *Aqua leviſſima pluviatilis eſt; deinde fontana, tum ex flumine, tum ex puteo; poſt hæc ex nive aut glacie; gravior his ex lacu; graviſſima ex paluae. Facilis etiam et neceſſaria cognitio eſt naturam ejus requirentibus. Nam levis pondere apparet, & ex his quæ pondere pares ſunt, eo melior quæque eſt, quo celerius et caleſit & frigeſcit, quoque celerius ex ea legumina percoquuntur* (o).

(n) *Vid.* Hoffmann Obſ. Chem. p. 140.

(o) Celſus Lib. 2. Cap. 18.

A recapitulation of the principal facts aſcertained by the preceding Experiments.

1. THE Mancheſter pump water is in general very hard and impure. It is impregnated with a large quantity of ſelenite, and contains alſo no inconſiderable proportion of alum.

2. THE hardeſt water will become ſoft and miſcible with ſoap, by the addition of ſalt of tartar. But ſuch a quantity of the vegetable alkali is required, to produce this effect on the Mancheſter pump water, as renders it offenſive to the palate, and unfit for common uſe.

3. HARD water is conſiderably ſoftened by boiling, contrary to the opinion of Dr. Heberden. For though heat generally increaſes the diſſolving

power of any *menſtruum*, at the ſame time it tends, in many inſtances, to deſtroy the texture, and diſunite the component parts of the ſolvend. Thus the groſſer ſalts contained in hard water are decompoſed by the boiling heat: The volatile vitriolic or muriatic acids fly off, leaving behind them an indiſſoluble, petrifying earth, which ſubſides to the bottom, and incruſts the veſſel. But the coction ſhould be continued fifteen or twenty minutes, to produce its full effect.

4. HARD water is ſoftened by being filtered through ſtone. And if it were firſt boiled a ſufficient length of time, and then filtered, it would be rendered tolerably pure, potable, and ſalutary, and at the ſame time much better adapted to a variety of culinary uſes.

5. Mr. Boyle aſſerts, that ſome pump waters, by expoſure to the ſun and air for a few days, will become ſoft enough to be miſcible with ſoap. But this is not the caſe with the hard water of Mancheſter.

6. Neither malt nor tea produce any ſoftening effect, on the hard water in which they are infuſed. Nor does fermentation improve or alter its nature. So that the wholeſomeneſs of malt liquors, muſt greatly depend upon the purity of the water, which is employed in their preparation.

7. Bricks harden the ſofteſt water, and give it an aluminous impregnation. The practice of lining wells with them, which is common in many places, is therefore very improper. Free-ſtone communicates no pernicious qualities to water.

8. Though by the tables of elective attractions it appears, that the acid of vitriol hath a ſtronger affinity to lead, than to the earth of alum, yet this metal does not ſeem to be ſoluble in aluminous waters.

9. Soft water, and eſpecially diſtilled water, acts far more powerfully as a *menſtruum* on vegetable bitters and aſtringents, than hard pump water. And it diſſolves reſinous bodies without any medium, or at leaſt with a much ſmaller proportion of mucilage of gum arabic, than is commonly employed.

10. Hard, aluminous waters are likely to ſucceed beſt in the dying of black, and in the preparation of ink.

11. Soft water is a much more powerful diſſolvent of quick-lime,

than hard water; at the ſame time that it covers and improves the harſh taſte of that acrid ſubſtance. The fragment of a human calculus was entirely reduced to a chalky powder, by being immerſed twelve days in lime water, prepared with diſtilled water; whereas another fragment of the ſame calculus ſuffered no viſible change in its texture, by being macerated an equal length of time in lime water, made with common pump water.

12. IN nephritic caſes, diſtilled water would be a good ſubſtitute for Malvern-water; for it is a powerful ſolvent of the human calculus.

FINIS.

Water
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